HIGH FREQUENCY COMMUNICATION SYSTEMS

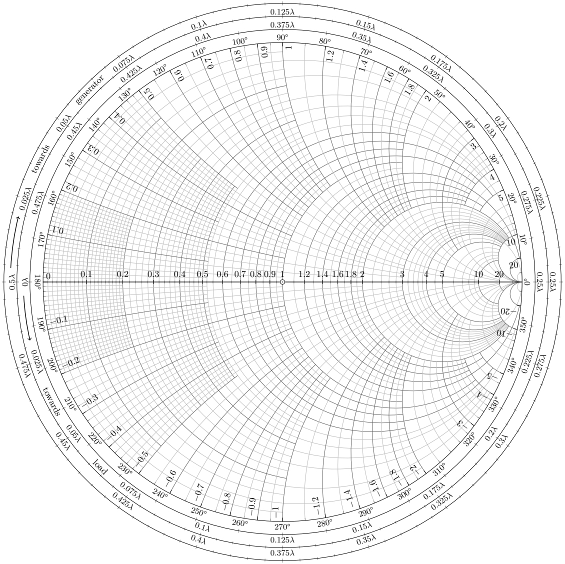
Lecture 5

Hasan T Abbas & Qammer H Abbasi

Spring 2021

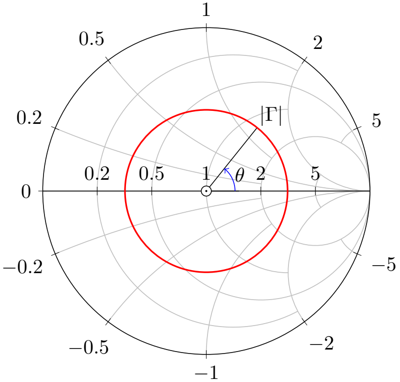
- The Smith Chart
- Load matching through stubs
- The Magic of Quarter-wave Transformer

THE SMITH CHART



- Developed by P Smith in 1939
- To this day, it is an integral part of microwave circuit design
- Provides a tool to visualise the transmission line phenomena such as impedance matching
- It is simply a polar plot of the reflection coefficient, Γ

- In polar coordinates, $\Gamma = |\Gamma|e^{j\theta}$
- We plot the magnitude as a radius ($|\Gamma| \leq 1$) from the centre
- The angle θ ranges from −180° to 180°
- The origin or the centre of the Smith chart is the ideal, matched point.



For lossles TLs, the *normalised* load impedance at $l = 0$ is a complex number:

$$z_L = \frac{Z_L}{Z_0} = \frac{1 + |\Gamma| e^{j\theta}}{1 - |\Gamma| e^{j\theta}}$$

Treating $\Gamma = \Gamma_r + j\Gamma_i$, the real and imaginary parts of z_L are:

$$r_L = \frac{1 - \Gamma_r^2 - \Gamma_i^2}{(1 - \Gamma_r)^2 + \Gamma_i^2}$$

$$x_L = \frac{2\Gamma_i}{(1 - \Gamma_r)^2 + \Gamma_i^2}$$

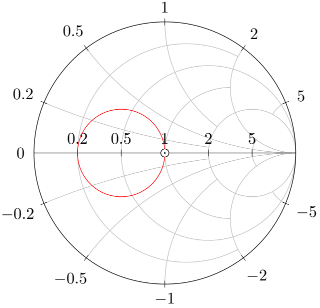
which can be written as two equations of circles:

$$\left(\Gamma_r - \frac{r_L}{1 + r_L}\right)^2 + \Gamma_i^2 = \left(\frac{1}{1 + r_L}\right)^2 \qquad \text{(Resistance Circle)}$$

$$(\Gamma_r - 1)^2 + \left(\Gamma_i - \frac{1}{x_L}\right)^2 = \left(\frac{1}{x_L}\right)^2 \qquad \text{(Reactance Circle)}$$

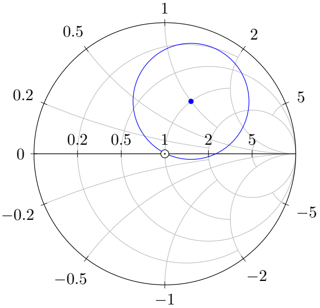
- Lets look at some examples
  - Taking $r_L = 1$ and lets plot in the Γ_r, Γ_i plane
  - But first, the equation for the resistance circle is:

$$\left(\Gamma_r - \frac{1}{1+1}\right)^2 + \Gamma_i^2 = \left(\frac{1}{1+1}\right)^2$$



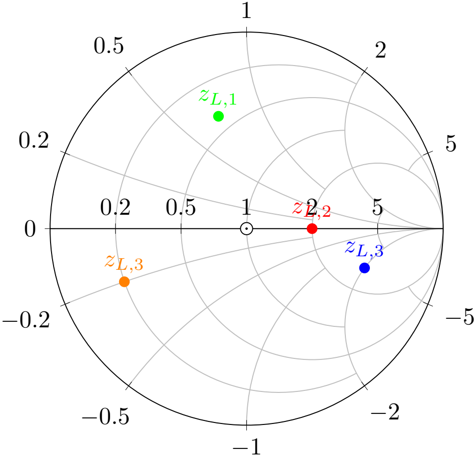
- Now the reactance circle where we take $z_L = j1 \implies x_L = 1$
- The reactance circle equation becomes:

$$(\Gamma_r - 1)^2 + (\Gamma_i - 1)^2 = 1$$



The top half is the *inductive* region and the bottom half is the

- We normally normalise the impedance to 50 Ω.
- However, the chart can be used for any value.
- $z_{L,1} = 0.4 + j0.7$
- $z_{L,2} = 2$
- $z_{L,3} = 3 - j2$
- $z_{L,4} = 0.2 - j0.2$



T

- Travelling along a transmission line is equivalent to rotation along a circle in the Smith chart
- On the Smith chart, different scales labels are provided that tell us which direction we need to consider